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X-ray analysis of Adularia and Moonstone, and the influence of temperature on the atomic arrangement of these minerals.

By

SHUKUSUKÉ KÔZU AND YOSHITOSHI ENDÔ.

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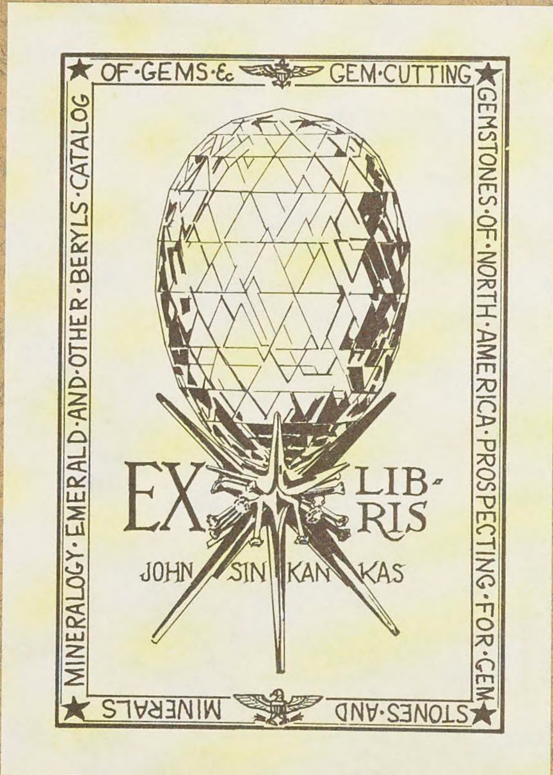
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X-ray analysis of Adularia and Moonstone, and the influence of temperature on the atomic arrangement of these minerals.

By

Shukusuké Kôzu and Yoshitoshi Endô.

With 8 Plates and 5 Textfigures.

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1. Introductory note.

The moonstone from Ceylon has been regarded by mineralogists as a variety of adularia with schillarization. However, on close examination from physical and chemical points, it is easy to show that very important differences exist between them. The refractive indices and the optic axial angles for different wave-lengths have been measured by one(1) of the authors. According to these figures,(2) the refractive indices and the

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(1) S. Kôzu, 'The dispersion phenomena of some monoclinic Felspars.' Mineralogical Magazine, 1916, Vol. XVIII, No. 82, pp. 253–273.

(2) The refractive indices and the optic axial angles, for sodium light, of the adularia and the moonstone are:—

	α	β	γ	2V
Adularia	1.5185	1.5225	1.5239	61°30′
Moonstone	1.5226	1.5270	1.5289	66 24

birefringences for the moostone are much higher than those for adularia, and the optic axial angle of the former is also greater than that of the latter. These differences may be assumed to be the result of the different molecular structure due to the different chemical composition, for it is well known that the refractive indices increase with the presence of soda. To ascertain the soda contents of adularia and moonstone, careful chemical analyses were made by Mr. K. Seto in the Petrological Laboratory of this University. The results are given in table I.

TABLE I.

	Adularia		Moonstone
	I	II	III
SiO_2	65.60	65.58	65.87
Al_2O_3	17.95	18.23	19.70
Fe_2O_3	none	none	none
MgO	0.30	none	trace
CaO	1.50	0.35	0.49
Na_2O	0.97	1.12	2.62
K_2O	14.01	14.70	12.06
Total	100.33	99.98	100.74

I. Adularia from St. Gotthard. The analysis was made of fragments cut from the crystal, of which the optical study has been already made by S. Kôzu.

II. Adularia from St. Gotthard. The crystal form is almost the same as before, showing a tripple twinning according to the Baveno-law and forming a rectangular prism. But the absence of crevices traversing parallel to the edge $(001) \wedge (101)$ in the basal plane is the prominent difference in habit from the former crystal. The refractive indices and the optic axial angle for sodium light are :—

α	1.5198
β	1.5234
γ	1.5249
$\gamma-\alpha$	0.0051
2V(calc.)	65° 18′
2V(obs.)	65° 4′

The optic axial plane is perpendicular to (010), and the optical character is nagative.

III. Moonstone from Ceylon. The fragments used for the analysis were the same as those used for the optical determination made by S. Kôzu.

All these crystals were kindly given by Prof. Lewis of Cambridge to one of the authors. He wishes to express his sincere thanks for this kindness on this occasion.

From the chemical table given above, we shall see that the two different crystals of adularia show almost the same composition, only a noticeable difference being in the lime content. If we compare the figures in column I with those given by Abisch,⁽¹⁾ a close resemblance, which may be taken as rather accidental, can be seen between them. The chemical composition of the moonstone, which is given in column III, differs essentially from that of adularia in alkalis. Though the difference are not very great, it is worth noting that they introduce an important problem which we shall try to discuss in the following pages.

The norms which were obtained by calculation from the three analyses given above are as follows:—

Adularia	I	$\mathrm{Or}_{84.1}$	$\mathrm{Ab}_{8.3}$	$\mathrm{An}_{7.6}$
	II	$\mathrm{Or}_{88.3}$	$\mathrm{Ab}_{9.3}$	$\mathrm{An}_{2.4}$
Moonstone	III	$\mathrm{Or}_{74.4}$	$\mathrm{Ab}_{23.1}$	$\mathrm{An}_{2.5}$

As will be seen in the above formulae, both crystals of adularia only contain about 9 percent of Ab molecule, while the moonstone contains 23 percent.

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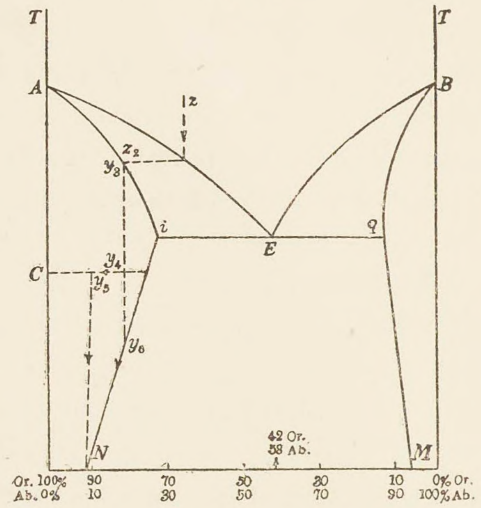
(1) A chemical composition of the St. Gotthard adularia, analysed by Abisch is

SiO_2	Al_2O_3	Fe_2O_3	CaO	Na_2O	K_2O	Total
65.69	17.98	tr.	1.34	1.01	13.99	100.00

It is generally believed by mineralogists and petrographers that orthoclase and albite form an imperfect isomorphous mixture, though some of them consider the mixture as one showing a relation of perfect mixed crystal with a minimum melting point, as given by Dittler's experiment.(1)

According to Vogt,(2) the eutectic composition lies in the region of Or : (Ab+An) : : 42 : 58, and at this temperature the mixture is composed of the two kinds of felspars, their chemical compositions being Or : Ab : : 72 : 28 and Or : Ab : : 12 : 88 respectively. Lately Warren(3) carefully determined by chemical and microscopical investigations the limits of admixture of (Ab+An) in Or and of Or in (Ab+An) at a lower temperature. The result is that Or may contain Ab up to a limit of about 10 percent, and Ab may contain Or up to about 8 percent. To make clear this relation, an equilibrium diagram drawn by Warren is shown again here (Fig. 1.).

Fig. 1.



If the stability relation suggested by Vogt and Warren is correct, it is evident that potassic alkali felspars, their original melt having Ab molecule more than about 10 percent, must dissociate into two different kinks of mixed crystal, sodic and potassic varieties, at certain temperatures lower than their solidus points. A well known perthitic structure is generally considered as a result of this way of dissociation. According to Warren's analysis and other chemical data, the perthitic structure occurs in potassic felspars, in which Ab molecule is present more than about 18 percent. From this point, the moonstone from Ceylon has a chemical composition which should be affected by the dissociation process. As is well known, when we observe the mineral by ordinary rays, it shows no trace of the perthitic structure, and appears perfectly homogeneous, as is seen in adularia, but differs from the latter by showing a peculiar phenomenon called schillarization.

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(1) E. Dittler, 'Die Schmeltzpunktkurve von Kalinatronfeldspäten.' T. P. M. M., 1912 Bd. 31, Heft. 4–5, S. 513–522.

(2) J. H. L. Vogt, 'Die Silikatschmeltzlösungen.' II, pp. 180–188.

" 'Physikalisch-chemische Gesetz der Krystallisationsfolge in Eruptivegesteinen'. T. P. M. M. 1905, Bd. 24, Heft. 6.

(3) C. H. Warren, 'A quantitative study of certain perthitic felspars'. Proceedings of the American Academy of Arts and Sciences, 1915, Vol. 51, No. 3, pp. 127–154.

The first object of the present study was to compare the manner of the atomic arrangements of adularia and moonstone, which have the chemical relation shown above. The influence of temperature on the atomic arrangement of these minerals was also examined. For the analysis by X-rays, the Laue's method was used and the results were quite satisfactory.

Warren,(1) following Mäkinen's observations, has also discussed an inversion point in potassic felspar (C in Fig. 1) at a temperature higher than 575°C. The mixed crystal is classified, on account of this, into two varieties α and β, and microcline belongs to the group of lower temperature, denoted as α. In the experiment carried out by us, we have also found an interesting point, at which the moonstone shows a distinct discontinuity in its thermal property.

Of the other kinds of alkali felspars from different localities, widely distributed, we have already almost finished the experiment on the same lines. The result will be published in the near future as the second contribution to the study of this subject.

2. *X-ray analysis of Adularia at ordinary temperature.*

As already described, the chemical analyses of adularia were made of two crystals, which show somewhat different habits. According to the results, one of them contains An molecule about 7.6 percent, while the other contains only 2.4 percent. The moonstone, of which we shall speak later, have also about the same amount of An molecule as the latter. So we have used for the X-ray analysis an adularia crystal containing 2.4 percent of An, for it makes comparison with the moonstone convenient. The norm of the adularia is given as $Or_{88,3}$ $Ab_{9,3}$ $An_{2,4}$

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(1) loc. cit. p. 142.

Mineral plates with a thickness of about 1 mm. were cut parallel to the base (001) and the side pinacoid (010) respectively. The Laue spots[1] produced by these plates are shown in fig. 1, Plate I, and in Fig. 1, Plate II, and the stereographic projection of the spots on (001) is given in the textfig. 2. In the projection, different diameters of black circlets were drawn by the different intensities of the Laue spots which appeared in the photographic plate. But the relation between the

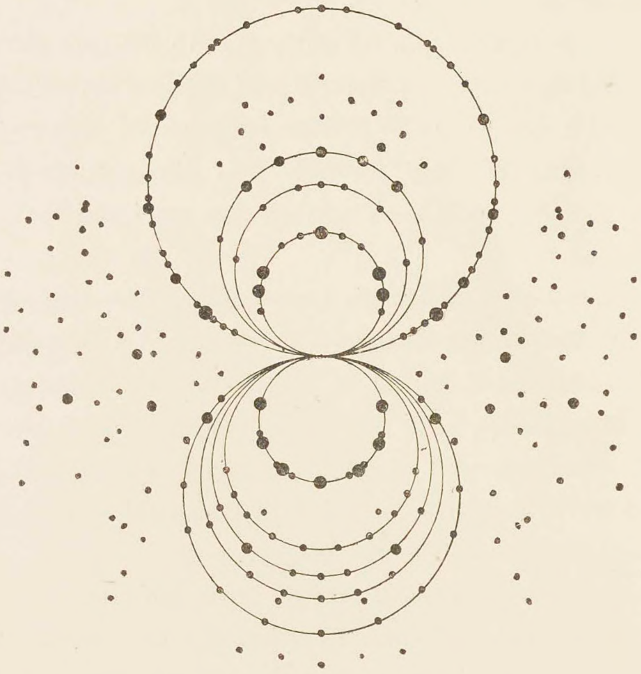

Fig. 2.

Stereographic projection of Laue spots of Adularia, (001).

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[1] Lauediagram of sanidine from Eifel has been already published by F. Rinne in 'Beiträge zur Kenntnis des Feinbaus der Krystalle', N. J., 1916, II Band, 2 Heft, S. 90.

diameters and the intensities of the spots were simply judged by the naked eye. It is evident that, as the spots are diffraction pattern of X-ray by atomic space lattice composing the mineral, the manner of the arrangement of the spots exactly indicates the manner of the atomic arrangement of a solid solution mixed of 88.3 Or, 9.3 Ab and 2.4 An. From the manner of the arrangement of the spots and of the variation of their intensities, we shall see that there is a plane of symmetry and that the plane coincides with that of the crystallographic symmetry—that is—the symmetry of the space lattice of the mineral agrees with that of the crystal form. In some cases in felspars, the symmetry of the space lattice does not agree with that of the crystal outline. The experimental result refering to this point will be described in the second contribution to the study of this subject.

3. X-ray analysis of Moonstone at ordinary temperature.

The X-ray analyses of the mineral were made of two kinds of crystals from different localities, Ceylon and Korea.(1) The latter crystal(2) also shows beautiful schillarization and from this property the mineral has been called moonstone. The mineral is reported as occuring as phenocrysts of liparitic rock, from which the crystals are easily separated. Their sizes vary from 10 mm. to 3 mm. in length and its chemical composition is given as $Or_{61.9}Ab_{32.7}An_{5.4}$.

The Laue spots of moonstone from Ceylon. As in the case of adularia, mineral plates were made parallel to the base (001) and the side pinacoid (010). Their Laue spots are given in Fig. 2, Plate I and in Fig. 2, Plate II, respectively, and the stereographic projection of the spots on (001) is shown in textfig. 3.

Comparing the spots of adularia and moonstone, it will be noticed that very remarkable and interesting differences exist between them. In adularia, all the spots are arranged on single circles, passing through the center of the figure, while those belonging to the base of the moonstone are in double circles. The relation is clearly seen in the stereographic projections. This evidently indicates that the atoms composing the moonstone are not distributed just like those of adularia, which forms one homogeneous solid solution, and that the atoms forming the moonstone are arranged in two different systems.

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(1) 咸鏡北道 明川郡 下古面 三郷里 甑山.

(2) N. Fukuchi, 'Mineralogy of Chosen.' Beiträge z. M. v. Japan, 1915, Nu. 5, 228.

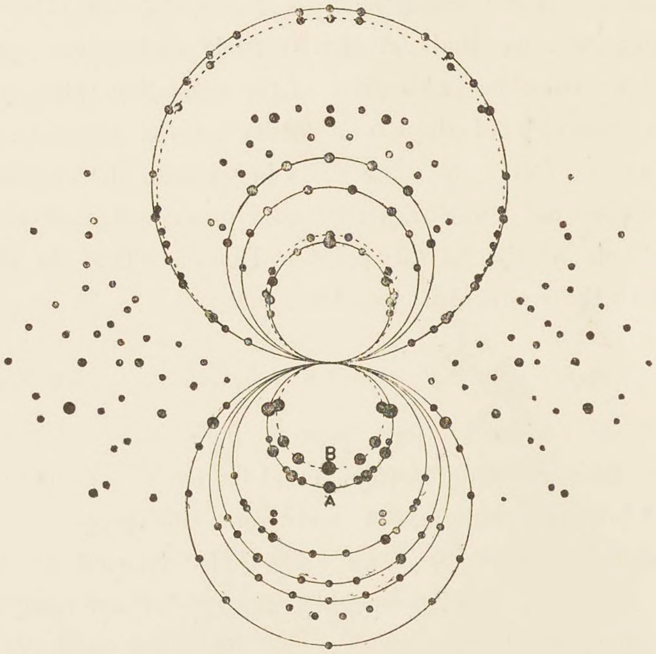

Fig. 3.

Stereographic projection of the Laue spots of Moonstone at ordinary temperature, (001).

This fact agrees well with what we should have expected from the chemical point of view, to which we have already referred. Hence, we may conclude that, a mixed crystal of 23.1 percent of Ab molecule and 74.4 percent of Or molecule, homogeneous at its solidus point, is made to dissociate by the lowering of temperature, and that the result of the dissociation can be easily detected by X-ray analysis. If this is so, it would seem highly probable that, the moonstone might again return to a homogeneous solid solution when heated to a higher temperature. To ascertain this and also to observe other thermal properties, the influence of different temperatures on the manner of the atomic arrsngement of the mineral was examined. The results of these experiments will be described in detail in the next chapter.

As to Vegard⁽¹⁾ and Schjedrup's study of solid solution by Bragg's method, the solid solution has such a structure that its components when mixed form a perfect structure and corresponding atom ions replace each other at random. But if our moonstone had a simple lattice, the Laue pattern would not be double. Neccessarily, to be double pattern the space lattice must not be simple and so we think that their case is one of simple and stable solid solution. However, there must be generally as many cases as Retgers⁽²⁾ and others have thought. For instance, Retgers regards the phenomena as purely mechanical, mixed crystal being formed of a series of thin homogeneous lattice. In the case of moonstone, the atoms of both components take their place in a combined configuration, and are not perfectly stable. This is the reason that why the pattern is double, and by thermal treatment its structure changes to stable equilibrium, which we shall describe in detail later. But its components are not pure potash-felspar and soda-felspar, they must be two kinds of solid solution, both having monoclinic symmetry.

From what is stated above, it is evident that there are two systems in the Laue spots of moonstone. In its stereographic projection, the spots referring to the atoms which form the sodic mixed crystal are connected by circles of dotted lines, and those belonging to the potassic crystal are connected by circles of full lines. In Fig. 3, only 12 circles are drawn as an example to show such relation.

The Laue spots on the side pinacoid of the mineral are also worth special attention (Fig. 2, Plate II). The general manner of the arrangement of the spots is similar to those of adularia, but the former differ from the latter in having many successive spots of lighter intensity between the main ones, which show much stronger and have a distinct outline.

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(1) L. Vegard u. H. Schjedrup, 'Die Konstitution der Mischkristalle.' Phys. Zeitsch., 1917, Vol. 18, Nu. 5, S. 93–96.

(2) Retgers. 'Das spezifische Gewicht isomorpher Mischungen.' Zeitsch. f. phys. Chem., 1889, Band 3, Heft 6, S. 497.

This evidently indicates that, the space lattice of the moonstone is not oriented homogeneously like that of adularia, and it is satisfactory evidence in support of our opinion founded on the mode of the arrangement of the spots on the base.

The Laue spots of moonstone from Korea.—An interesting difference between this crystal and the moonstone from Ceylon is found in the orientation of the space lattice. As described above, the spots on the base of the latter are arranged in double circles and those on the side pinacoid are connected by many spots of lighter intensity; in the moonstone from Korea the relation is just the reverse, the distinct double spots appear on the side pinacoid and the successive one on the base. These figures are given in Fig. 3, Plate I, and in Fig. 3, Plate II.

4. The influence of temperature on the atomic arrangement of Adularia and Moonstone.

For heating, a platinum resistance furnace was used, and the temperatures were measured with the Pt : Pt-Rd thermoelement in connection with a potentiometer. The lowest temperature applied for cooling the material under examination was that of liquid-air. A similar experiment for the slow rate of cooling was also made. The results obtained by these experiments will be detailed in the following pages.

Adularia.—The mineral plate parallel to (001), about 1 mm. thick, kept at 1060°C for 1 hour and 18 minutes was quenched in mercury and then analysed by X-rays. The result is shown in Fig. 4, Plate II. Comparing this figure with that at the ordinary temperature, we see that there is no recognisable difference between them, in other words, no effect of temperature on the space lattice of the mineral was observed, so far as this method is concerned. Hence we may conclude that the crystal structure of the adularia, which forms a solid solution of chemical composition already given, is stable for the whole range of temperature in a crystalline state.

Moonstone from Ceylon.—The experiments of heat treatment and

TABLE II.

No. of experiment	Temperature in degrees Centigrade.	Time in hours and minutes.	Remarks.
1	494°	4^{h} 30^{m}	Quenched in Hg of room temperature.
2	594	18 0	,,
3	690	1 30	,,
4	753	8 0	,,
5	825	10 0	,,
6	874	18 0	,,
7	1063	21 30	,,
8	1088	1 30	,,
9	1115	1 30	,, The commencement of fusion was noticed at this temperature.
10	1138	1 30	The fusion is well observed on the surface of the mineral plate.
11	1160	1 30	,,
12	1190	1 28	The fusion appears to the naked eye to be complete.
13	1249	46	The fusion is complete.
Heating for a short time.			
14	956	30	Quenched in Hg.
15	952	10	,,
16	1180	20	,,
Slow rate of cooling.			
17	875–205	5 25	The mineral was kept for 30 minutes at the maximum temperature.
18	994– 87	9 8	The mineral was kept for 40 minutes at the maximum temperature.
19	700–372	1 40	The mineral was kept for 30 minutes at the maximum temperature.
Quenching in liquid-air.			
20	25 (room temperature)		Quenched in liquid-air.
21	875		,,

X-ray analysis for this mineral were made of plates cut parallel to (001). The data of the thermal experiments are given in Table II.

The results of the X-ray analyses of the mineral plates at the different temperatures given in Table II are shown in 22 figures, Plate III—VIII. These figures are reproductions taken from original photographs, with the exception of those of the slow rate of cooling, these being original ones.

The Laue spots obtained by experiment No. 1 (temp. 499°C) only differ from those of the ordinary temperature in decreasing slightly the intensity of the spots belonging to the sodic felspar molecule, while at temperatures higher than this these spots not only decrease their intensities, but, by raising the temperature, the circles connecting the spots change their positions and approach continuously to those of the potassic felspar molecule. At a temperature (Textfig. 4) between 1060°C

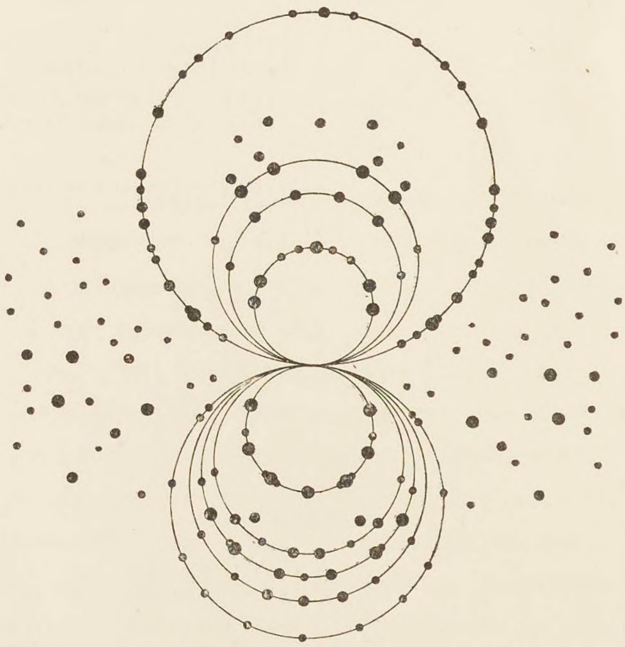

Fig. 4.
Stereographic projection of the Laue spots of Moonstone, heated up to 1088°C.

and 1115°C, which can be taken as the solidus point, the circle of the former system falls on the latter, and the Laue spots thus obtained are similar to those of adularia. To obtain a general idea of the rate of change of the positions of the spots, the distance between two spots A and B as seen in Fig. 3 at different temperatures were measured approximately on the negative plate of the original photographs, and these values were plotted against the corresponding temperatures. The diagram is given in Fig. 5.

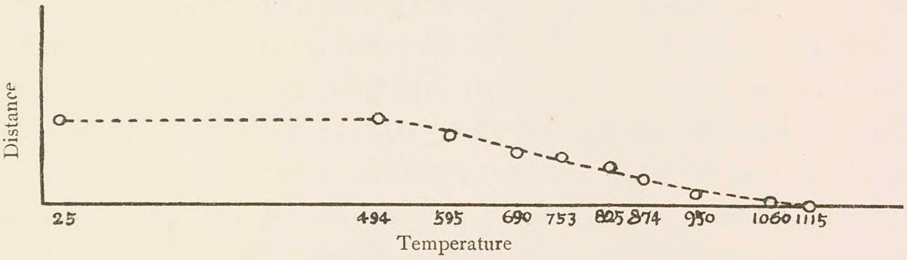

Fig. 5.

It will be seen in the diagram that, from ordinary temperature up to about 500°C, there is almost no change in the position of the spots; however at higher temperatures, point B approaches continuously to point A, and finally the former falls on the latter at a temperature between 1060°C and 1115°C.

The commencement of the fusion of the mineral was recognized by its milky luster newly produced by the heat treatment. This temperature is 1115°C. The Laue spots at this temperature increase their sizes, which may be explained as the result of irregular atomic arrangement, effected by accelerated oscillation at a temperature at which fusion commences. At higher temperature, the spots decrease their intensities, which indicates that the space lattices are broken gradually into unorderly arrangement of an amorphous state. At 1190°C the spots almost disappeared and faint radial images corresponding to their original arrangement are observed. This clearly shows that 1190°C is a temperature in the melting interval, but very close to the liquidus point. A similar image is often observed in Röntgen patterns of quenched metals; in such cases, the image is generally taken as the result of the interference due to minute recrystallized bodies, while in the case of such silicate minerals, the relation is different and it is no doubt thinkable that the diffraction pattern mentioned above is due to the remainder of the crystalline part still undissolved. To ascertain this, the mineral heated up to 1249°C was quenched in the same way as before and analysed. The result was a perfectly amorphous substance as seen in Fig. 4, Plate VI.

The heat effect for a short time on the Laue spots was also examined. The Röntgen pattern of these mineral plates, kept at 952°C for 10 minutes, at 956°C for 30 minutes, and at 1180°C for 20 minutes are given in Fig. 2, Plate VIII, in Fig. 3, Plate IV, and in Fig. 2 Plate VI respectively. In these cases, the changes influenced by heat will be seen to be fairly rapid.

The influence of cooling at a slow rate on the Laue spots is remarkable and interesting. In the first of these experiments, the mineral plate kept at 994°C for 40 minutes was gradually cooled until 87°C in 9 hours and 8 minutes; and in the second, the plate kept at 875°C for 30 minutes was cooled to 205°C in 5 hours and 25 minutes, these cooling curves being given in Fig. 3, Plate VIII. In the two cases, the spots belonging to the sodic felspar molecule appear in double, or triple if we include the spots belonging to the potassic felspar molecule (Figs. 1 and 2, Plate VII). The outer spots of the sodic molecule appear in the positions corresponding to the maximum temperature applied in the experiments, while the inner ones to those of a lower temperature. It is especially interesting to note that the positions of these innermost spots in the two cases are the same distance from the outermost ones, which belong to the potassic felspar molecule. From this distance, a temperature corresponding to the position is estimated as nearly 700°C. This is easily proved by the third experiment. The maximum temperature applid to the mineral was 700°C and then it was cooled gradually. The spots for sodic felspar, which were formerly double, are exactly single in this case as seen in Fig. 4, Plate VII. It is highly probable that this temperature is a transition point for this kind of felspar.

In the next three experiments, we have examined the effect of a low temperature on the atomic arrangement, using liquid-air. In the first case, the mineral plate at ordinary temperature was immersed in liquid-air and analysed by X-ray, and there was no noticeable difference in the spots compared with those at the ordinary temperature. In the second, the mineral plate, which was cooled gradually from 875°C to the room temperature (about 25°C), was chilled in liquid-air; and in the third, this plate was again heated up to 875°C and then quenched in the same way. The Laue spots of the second case are shown in Fig. 1, Plate VIII, and of the third in Fig. 2, Plate VIII. From these figures, we also see that there is no difference in the spots compared with those obtained by the mineral plate at an ordinary temperature or those chilled in mercury of the room temperature.

5. The cause of schillarization in Moonstone.

Schillarization is no other than the dispersion phenomenon produced by diffraction of ordinary light, which once entered a crystal. From the mineralogical standpoint, it is generally considered that there are different causes which produce diffraction,—orderly arrangement of minute inclusions, negative crystals, fine lamellae of twinning, etc.

In the case of the moonstone from Ceylon, there is no trace of negative crystals or of fine lamellae of twinning, and it is free from inclusions, which are orderly arranged. Hence there must be another cause which gives to the crystal this well known property.

In the course of our thermal experiments, we have noticed that, the intensity of schillarization becomes lighter by raising the temperature, and at a higher temperature than 1000°C this property almost disappears. So we imagine that the schillarization might be due to the arrangement of two diffierent system of the space lattice forming the crystal. In order to prove this, we have examined by X-ray in the same way, other crystals of alkali felspars, which show beautiful schillarization and are expected to have such a stability relation as the moonstone, in order to discover whether they exhibit the double system of the Laue spots or not. For this purpose, so-called moonstone from Korea and soda-orthoclase from Frederikovärn, Norway, were analysed, and we have found that, the results appeared according to anticipation, as seen in Figs. 3 and 4, Plate II. These crystals also lost their beautiful shining when heated to 790°C and 1100°C, respectively.

We may, therefore, conclude that the schillarization is the result of interference of visible rays, caused by a special manner of arrangement of the net planes of the space lattice, which consists of two different systems, and these two kinds of net planes must be arranged in such a way as to be suitable to produce the interference of ordinary light.

6. *Summary.*

1. In order to obtain a general idea of the crystal structures of adularia ($Or_{88.3}$ $Ab_{9.3}$ $An_{2.4}$) from St. Gotthard and of moostone ($Or_{74.4}$ $Ab_{23.1}$ $An_{2.5}$) from Ceylon, these two crystals were analysed by X-ray. It was found that, the adularia consists of one system of space lattice, from which it can be taken as forming an homogeneous solid solution; while the moonstone consists of two, from which we may conclude that in the mineral two kinds of solid solution coexist. This difference is in accordance with what we expected from their chemical properties-viz. composition and limited miscibility in the solid solution.

2. The influence of temperature on the Laue spots of adularia was examined, and it was observed that no special change appeared at two different temperatures, 25°C and 1060°C, from which we may conclude that the crystal structure of adularia is stable for almost the whole range of temperature in the crystalline state.

3. The same experiments were made for the moonstone, and very interesting and important results were obtained.

A. By raising the temperature, one of the two different systems of the Laue spots commences to decrease their intensities and shift gradually toward the other and finally they become one system.

B. By lowering the temperature slowly, the Laue spots appearing in one system at a high temperature begin to separate into two systems, and one parts gradually from the other until the temperatue reaches 700°C, at this point the spots remain unmovable even when the temperature is lowered.

C. When chilled in liquid-air, there was no special difference in the spots compared with those of the room temperature.

4. The cause of schillarization in moonstone was found to depend on a special manner of arrangement of the net planes of the space lattice.

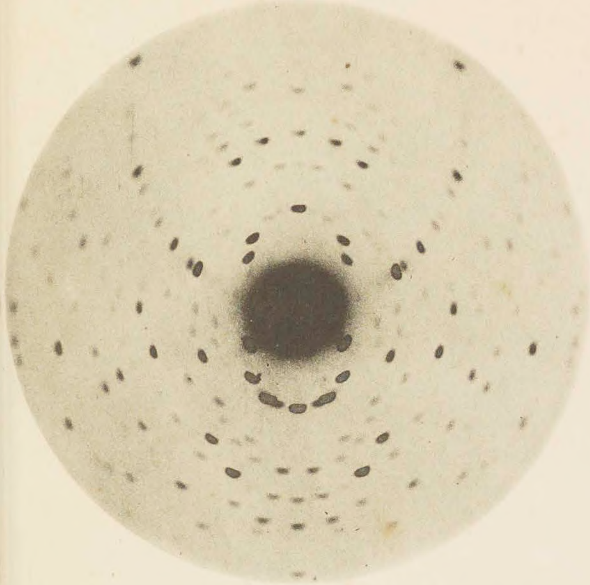

Fig. 1. Adularia from St. Gotthard, (001), ordinary temperature.

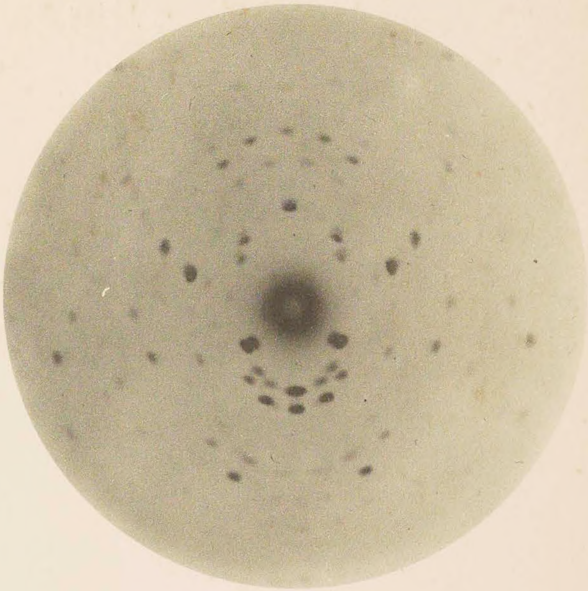

Fig. 2. Moonstone from Ceylon, (001), ordinary temperature.

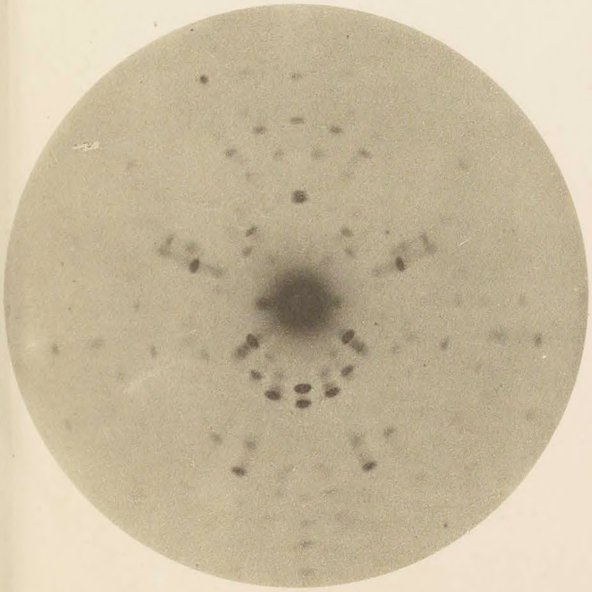

Fig. 3. Moonstone from Korea, (001), ordinary temperature.

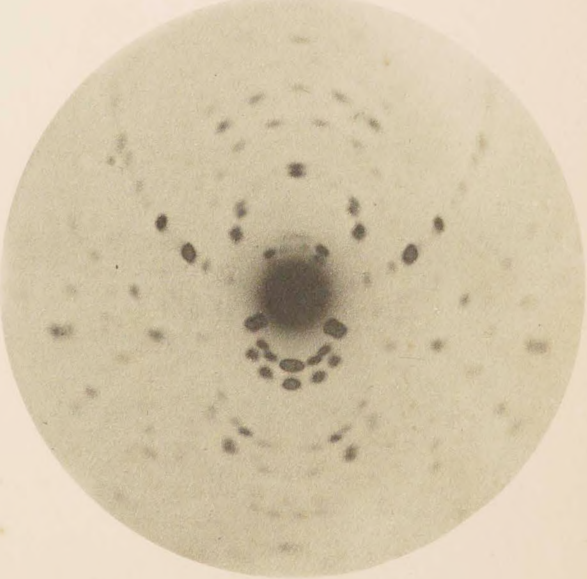

Fig. 4. Soda-felspar from Frederikovärn, (001), ordinary temperature.

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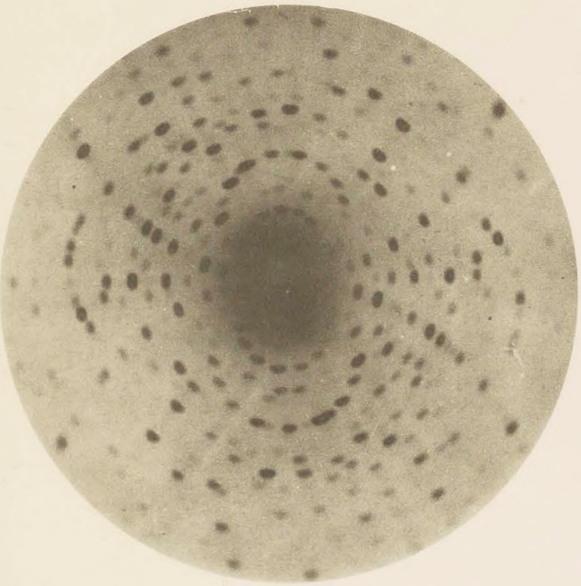

Fig. 1. Adularia from St. Gotthard, (0$\bar{1}$0), ordinary temperature.

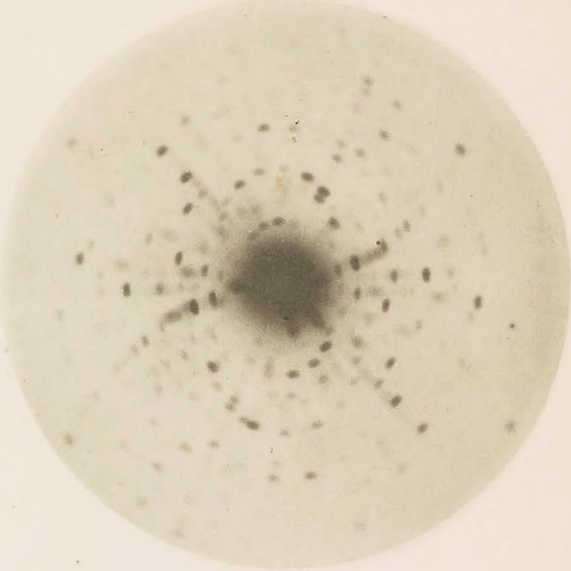

Fig. 2. Moonstone from Ceylon, (010), ordinary temperature.

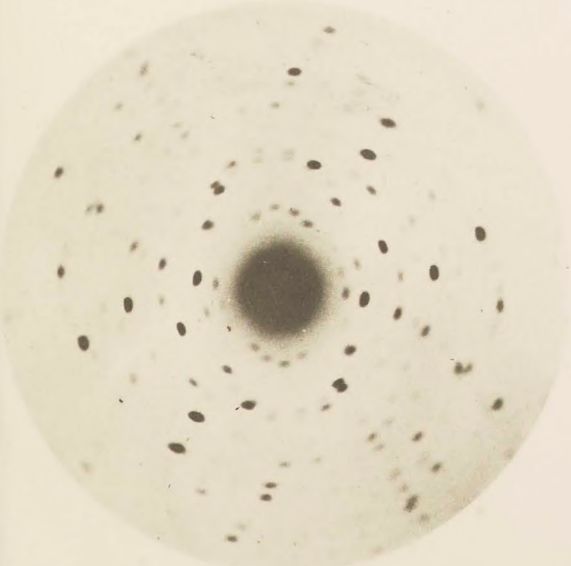

Fig. 3. Moonstone from Korea, (0$\bar{1}$0), ordinary temperature.

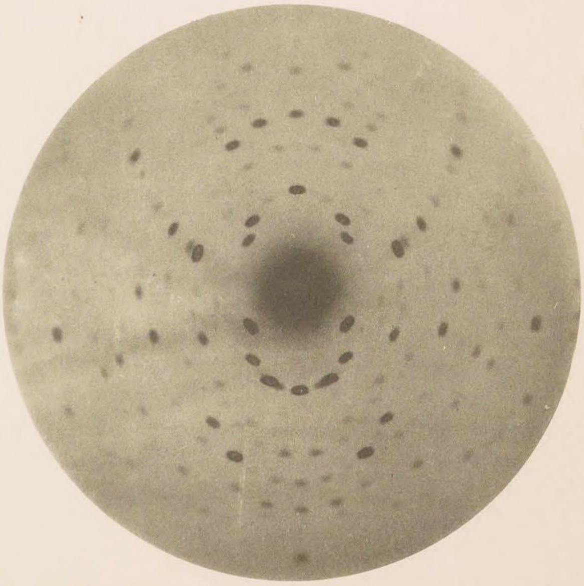

Fig. 4. Adularia from St. Gotthard, (010), heated up to 1060° C.

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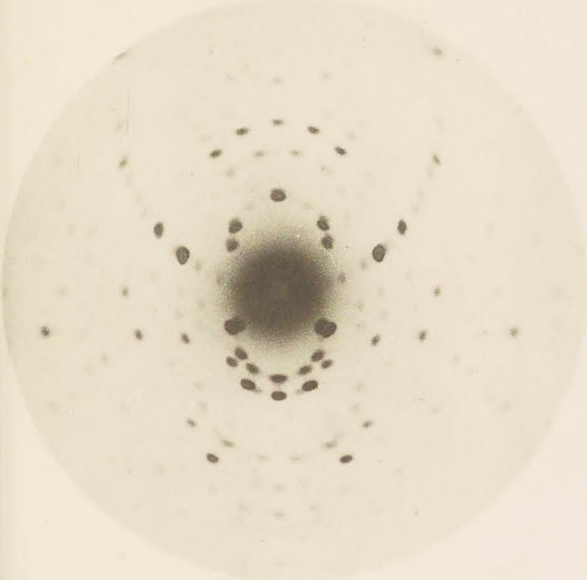

Fig. 1. Moonstone from Ceylon, (001), 494° C, 4 hrs 30 ms.

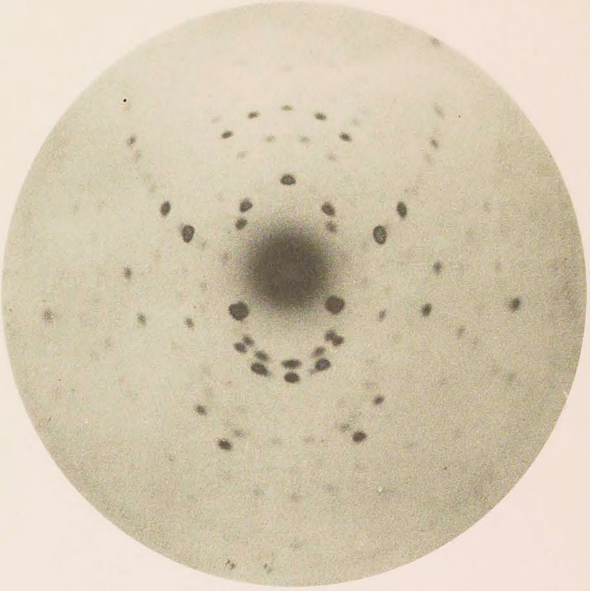

Fig. 2. Moonstone from Ceylon, (001), 595° C, 18 hrs.

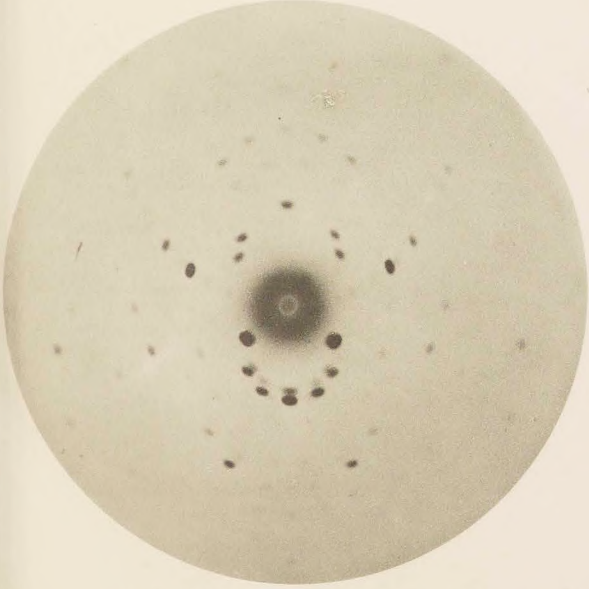

Fig. 3. Moonstone from Ceylon, (001), 690° C, 1 hr 30 ms.

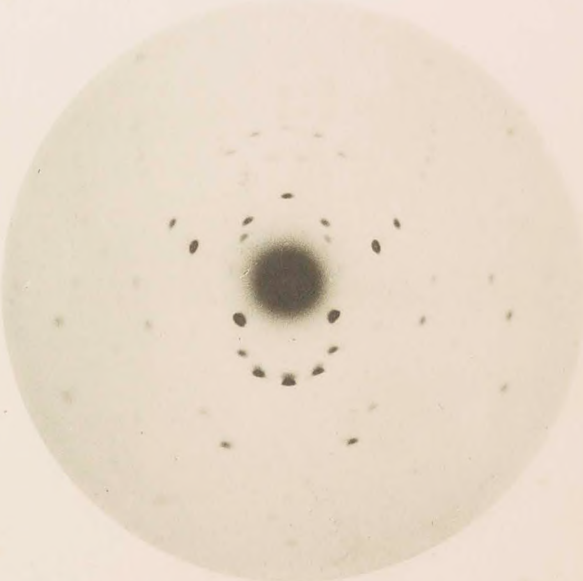

Fig. 4. Moonstone from Ceylon, (001), 753° C, 8 hrs.

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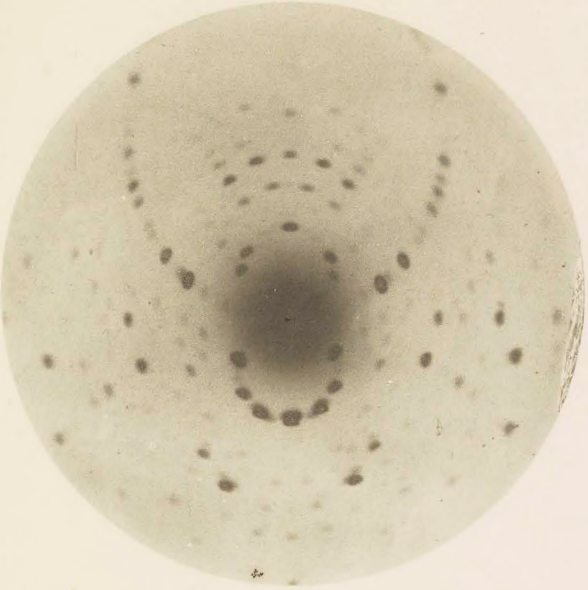

Fig. 1. Moonstone from Ceylon, (001),
825° C, 10 hrs.

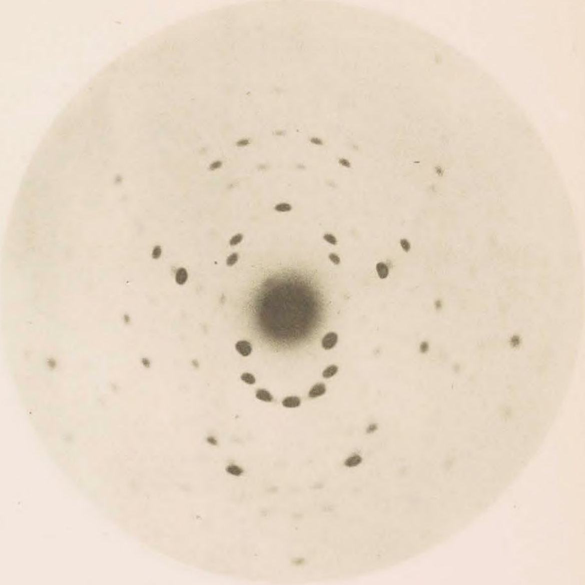

Fig. 2. Moonstone from Ceylon, (001),
874° C, 18 hrs.

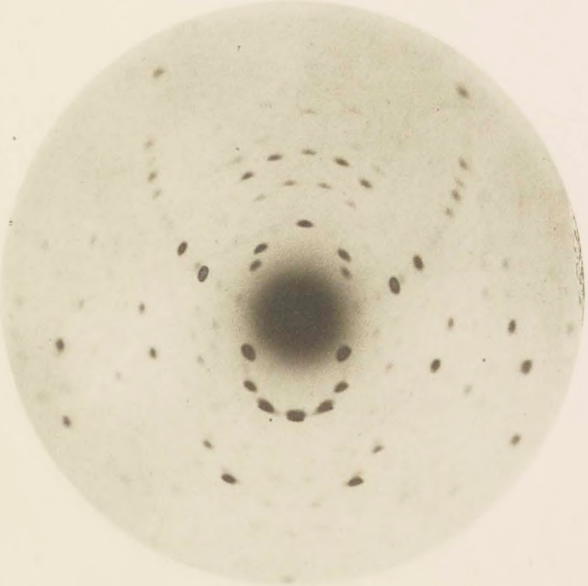

Fig. 3. Moonstone from Ceylon, (001),
956° C, 30 ms.

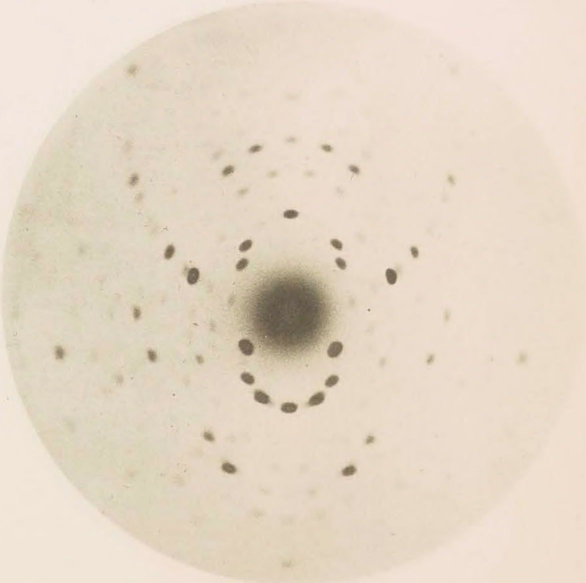

Fig. 4. Moonstone from Ceylon, (001),
1063° C, 21 hrs 30 ms.

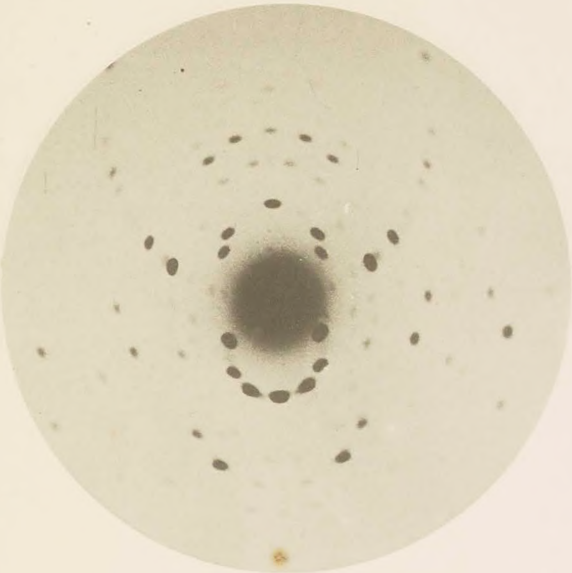

Fig. 1. Moonstone from Ceylon, (001), 1088° C, 1 hr 30 ms.

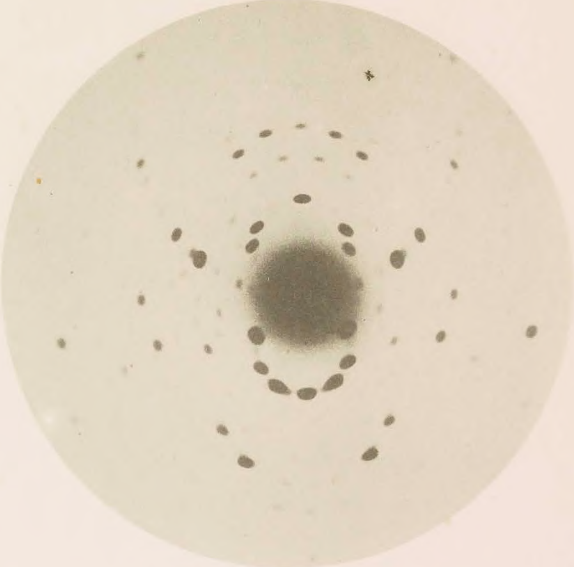

Fig. 2. Moonstone from Ceylon, (001), 1115° C, 1 hr 30 ms.

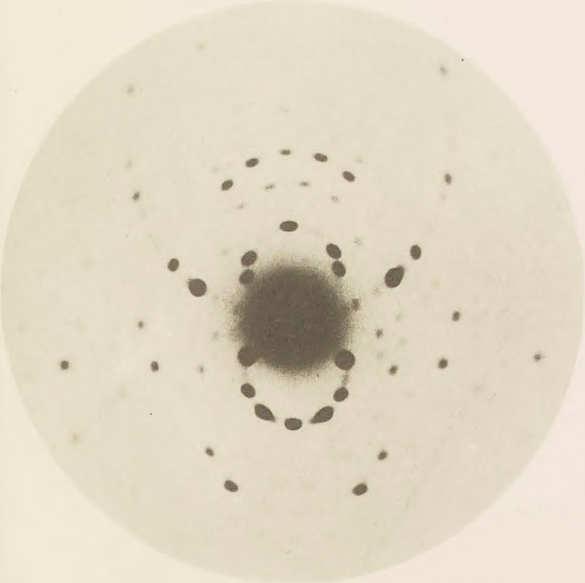

Fig. 3. Moonstone from Ceylon, (001), 1138° C, 1 hr 10 ms.

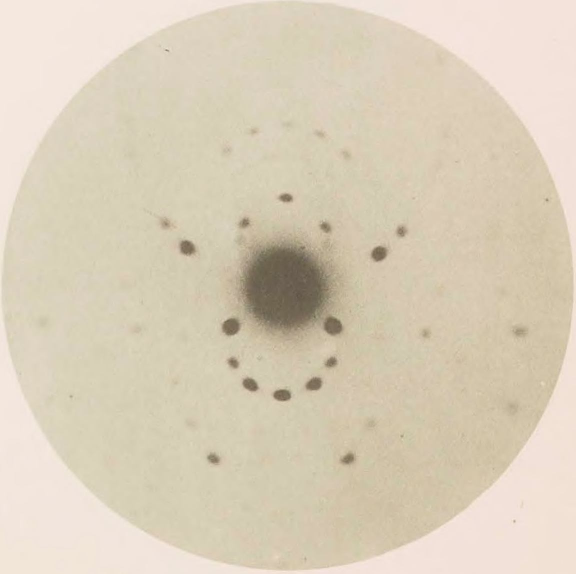

Fig. 4. Moonstone from Ceylon, (001), 1160° C, 1 hr 30 ms.

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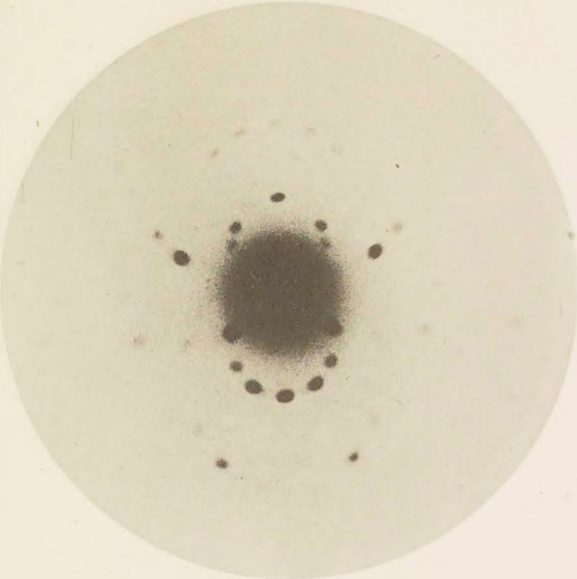

Fig. 1. Moonstone from Ceylon, (001), heated at 1180° C, for 20 ms, quenched and again heated at the same temperature for 30 ms.

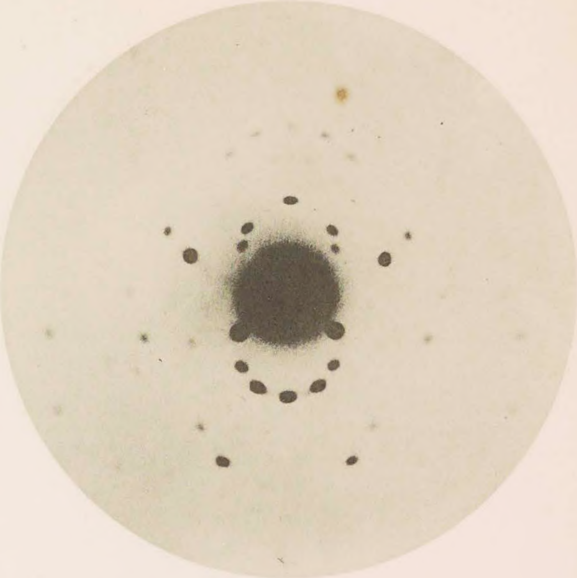

Fig. 2. Moonstone from Ceylon, 1180° C, 20 ms.

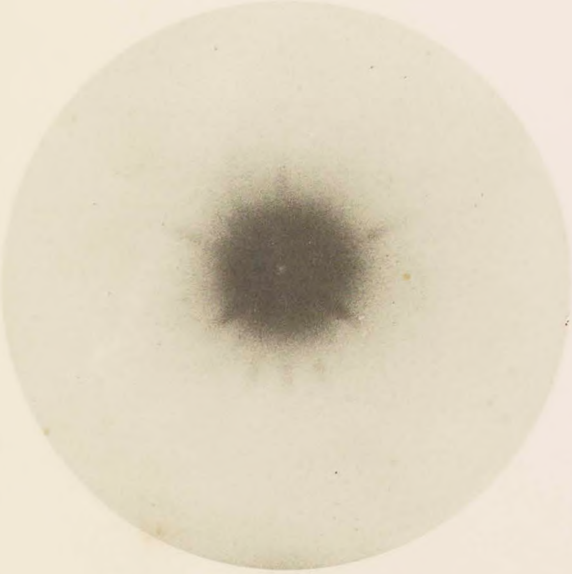

Fig. 3. Moonstone from Ceylon, 1190° C, 1 hr 30 ms.

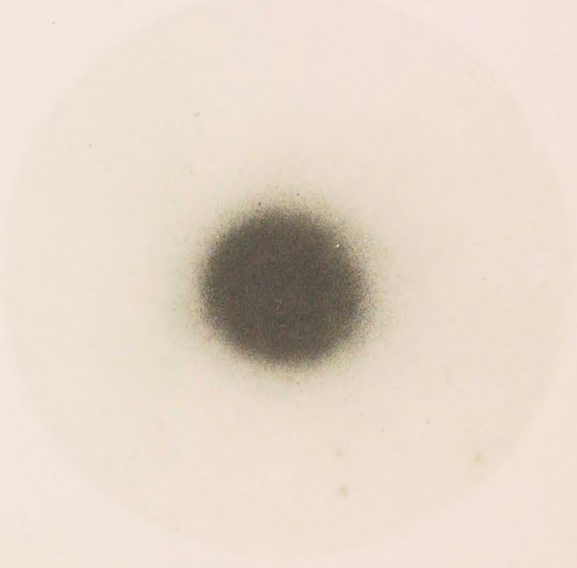

Fig. 4. Moonstone from Ceylon, 1249° C, 46 ms.

S. Kôzu and Y. Endô: X-ray analysis of Adularia and Moonstone.

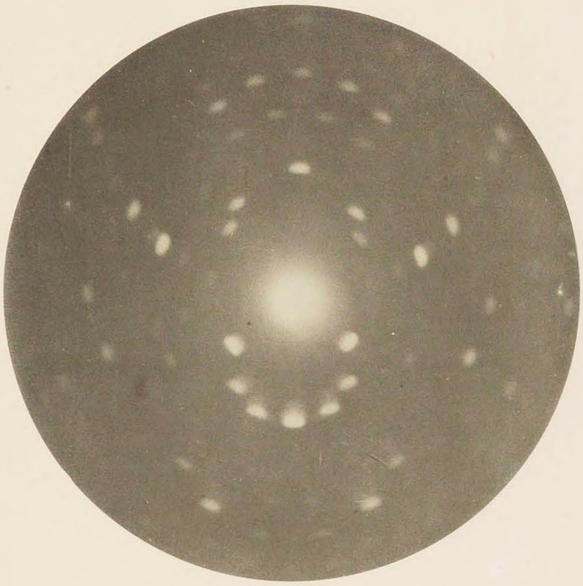

Fig. 1. Moonstone from Ceylon, (001), slowly cooled from 875° C, to 205° C, for 5 hrs 25 ms.

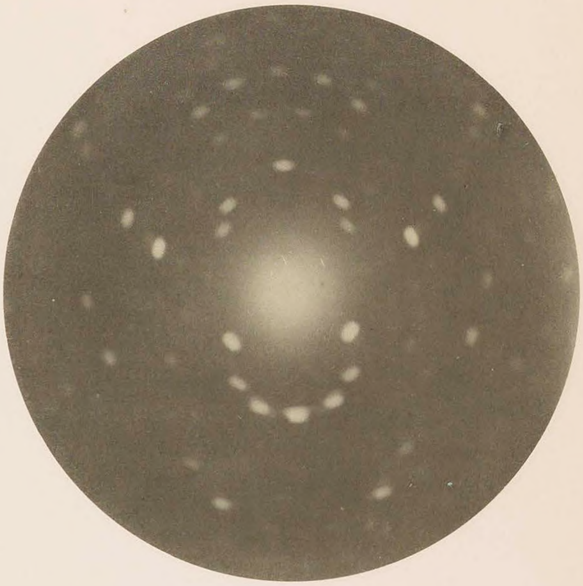

Fig. 2. Moonstone from Ceylon, (001), slowly cooled from 875° C, heated again to 875° C, then quenched in liquid-air.

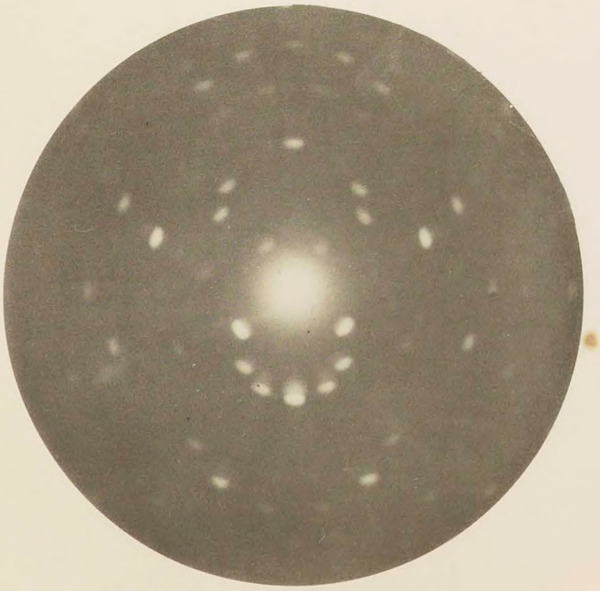

Fig. 3. Moonstone from Ceylon, (001), slowly cooled from 994° C, to 87° C, for 9 hrs 40 ms.

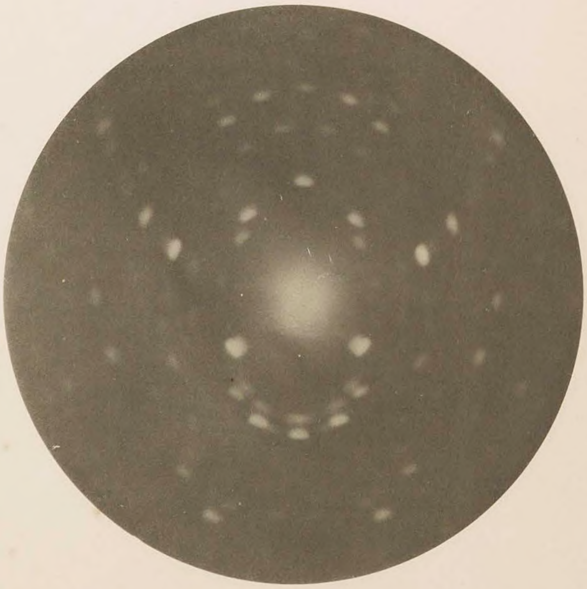

Fig. 4. Moonstone from Ceylon, (001), slowly cooled from 700° C, to 372° C, for 1 hr 40 ms.

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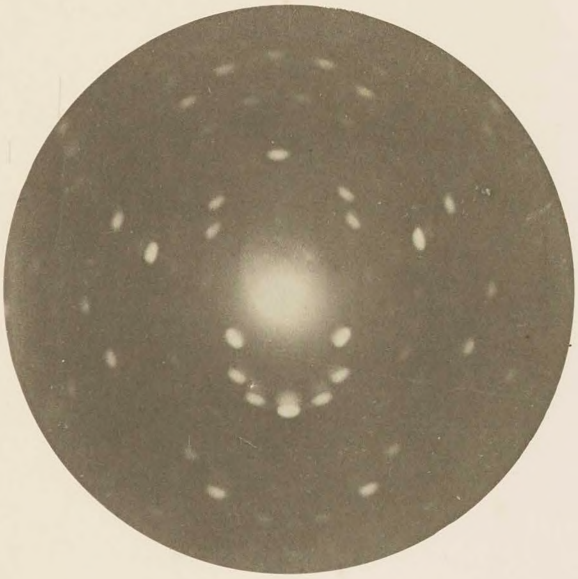

Fig. 1. Moonstone from Ceylon, slowly cooled from 875° C, to room temperature, then cooled in liquid-air.

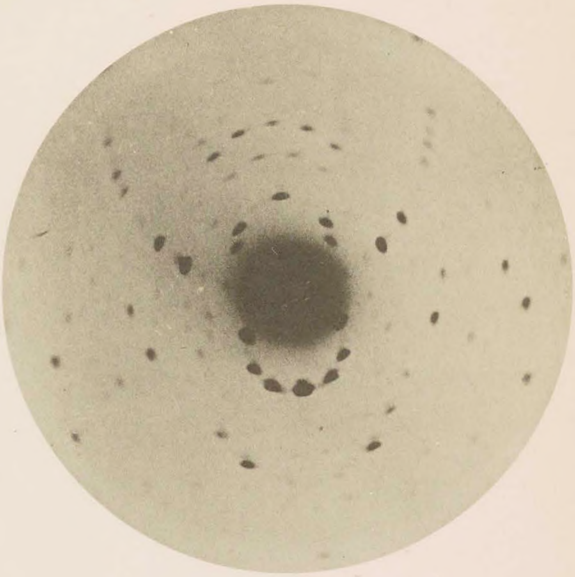

Fig. 2. Moonstone from Ceylon, 952° C, 10 ms.

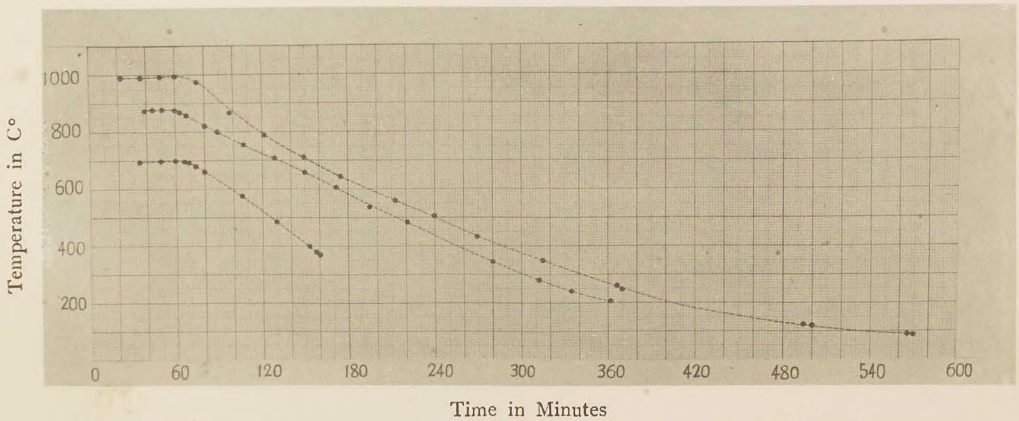

Fig. 3. The diagram shows the rate of cooling of the mineral plates, their Laue spots being given in Figs. 1, 3 and 4 in Plate VII.

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